

PAID
LIBRARY
STORAGE

VOL. XI.

BULLETIN

NO. 6

IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

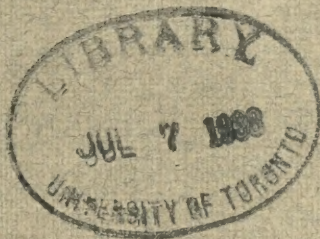
MARCH, 1913

Published Monthly by the Iowa State College of Agriculture and Mechanic Arts.
Entered as Second-class Matter, October 26, 1905, at the Postoffice at
Ames, Iowa, under the Act of Congress, July 16, 1904.

Physical &
Applied Sci-
ences
Engineering

BULLETIN NO. 32

Engineering Experiment Station



A TOPOGRAPHICAL SURVEY
OF THE
SPIRIT AND OKOBOJI LAKES REGION

By

H. C. Ford

AMES, IOWA

PURPOSE OF THE STATION

THE purpose of the Engineering Experiment Station is, first, to afford a service for the other industries of Iowa, similar to that afforded by the Agricultural Experiment Station to the agricultural industries; second, to assist the urban population of the state in solving the technical problems of urban life; third, to solve the purely engineering problems of the agricultural population and industries of the state.

VOL. XI.

BULLETIN

NO. 6

IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

MARCH, 1913

Published Monthly by the Iowa State College of Agriculture and Mechanic Arts.
Entered as Second-class Matter, October 26, 1905, at the Postoffice at
Ames, Iowa, under the Act of Congress, July 16, 1904.

BULLETIN NO. 32

Engineering Experiment Station



A TOPOGRAPHICAL SURVEY
OF THE
SPIRIT AND OKOBOJI LAKES REGION

Made by the Civil Engineering Students
of Iowa State College.

By

H. C. Ford, C. E.
Associate Professor of Civil Engineering

AMES, IOWA

ENGINEERING EXPERIMENT STATION

STATION COUNCIL

(Appointed by the State Board of Education)

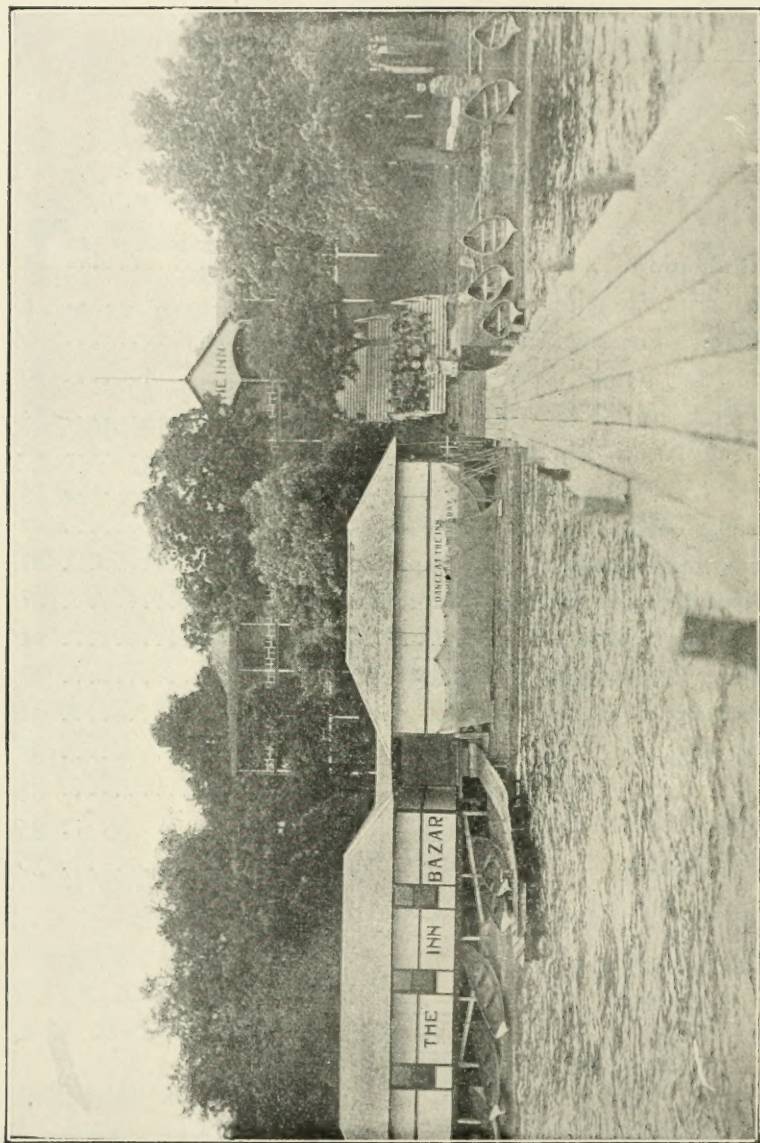
RAYMOND A. PEARSON, LL. D.	President
ANSON MARSTON, C. E.	Director
LOUIS BEVIER SPINNEY, B. M. E.	Professor
SAMUEL WALKER BEYER, B. S., Ph. D.	Professor
WARREN H. MEEKER, M. E.	Professor
FRED ALAN FISH, M. E. in E. E.	Professor
JAY BROWNLEE DAVIDSON, B. S., M. E.	Professor

ENGINEERING EXPERIMENT STATION STAFF

RAYMOND A. PEARSON, LL. D.	President, Ex-Officio
ANSTON MARSTON, C. E.	Director and Civil Engineer
LOUIS BEVIER SPINNEY, B. M. E. ..	Illuminating Engineer
SAMUEL WALKER BEYER, B. S., Ph. D. ..	Mining Engineer
WARREN H. MEEKER, M. E.	Mechanical Engineer
FRED ALAN FISH, M. E. in E. E.	Electrical Engineer
JAY BROWNLEE DAVIDSON, B. S., M. E.	
.....	Agricultural Engineer
IRA A. WILLIAMS, M. S., A. M.	Ceramist
JOHN EDWIN BRINDLEY, A. M., Ph. D.,	
.....	Engineering Economist
GEORGE A. GABRIEL, B. S. in Chem.	Industrial Chemist
CHARLES S. NICHOLS, B. C. E.	Assistant Director
A. O. ANDERSON, B. S. in Mn. E.	
.....	Assistant Engineer in Civil Engineering
HERBERT W. WAGNER, B. S. in E. E.	
....	Assistant Engineer in Mechanical and Electrical Engineering
MILTON F. BEECHER, B. S. in Ceramics	
OTTO M. SMITH, B. S.	Assistant Chemist

TABLE OF CONTENTS.

	Page
Introduction	5
Historical Sketch	5
Organization and Management.....	6
The Area Being Surveyed.....	10
General Outline of Work.....	12
Triangulation Stations	12
Base Line Measurement.....	14
Triangulation	17
Azimuth Determinations	21
Calculation of Triangulation.....	21
Leveling	21
Taking Topography	28
Sounding	31
Mapping	35
Maps	35
Data	35
Conclusion	36



"The Inn" as seen from the end of the dock.

INTRODUCTION.

The Civil Engineering Department of Iowa State College holds, during the first two weeks of June in each year, a Summer Surveying Camp. It is required of each civil engineering student that he attend, during his four years' course, at least one of these camps, but he has the option of attending two others, or of securing engineering work of satisfactory grade during each of two summer vacations, putting in at least four weeks' work in each vacation.

The purpose of the Summer Surveying Camp is, primarily, to give the students practice in surveying on a somewhat larger scale than is practicable during the school year. This purpose is kept constantly in mind, and all other considerations, accuracy alone excepted, are made subordinate thereto. As soon as a student becomes familiar with the duties of one position, he is shifted to another, and the work is so arranged that every student is given experience of as varied a character as possible. It is evident that under such conditions speed is not attainable, and the time spent is many times greater than would be required with experienced men. It should be understood, however, that every precaution has been taken to insure the accuracy of the work, and while errors have been made, as would be expected under the circumstances, yet the methods have been such that these errors have been found and corrected, so that the final accuracy of the work is assured.

The work done at the Summer Surveying Camps consists of making a topographic survey and map of some specified area. In selecting the area to be surveyed the points kept in mind are:—accessibility, suitability for the purpose in hand, and value to the state of the completed map. The area is made large enough so that the work will be in one locality for a number of years, making it possible to plan the work ahead and thus secure better results. Making headquarters at the same place for several years also simplifies the making of the necessary annual arrangements and the problems of management.

HISTORICAL SKETCH.

Previous to the summer of 1905 the Summer Surveying Camp was held along the Des Moines River, near the town of Moingona, in Boone County. Since that time the work has been in the Spirit and Okoboji Lakes Region, in Dickinson County, where there is being surveyed an area of seventy-seven square miles, something more than fifty per cent of which has been completed to date.

It is the purpose of this bulletin to make public the map in its present state, and to describe the work so far done, leaving the final map and a discussion of the entire survey for a later bulletin.

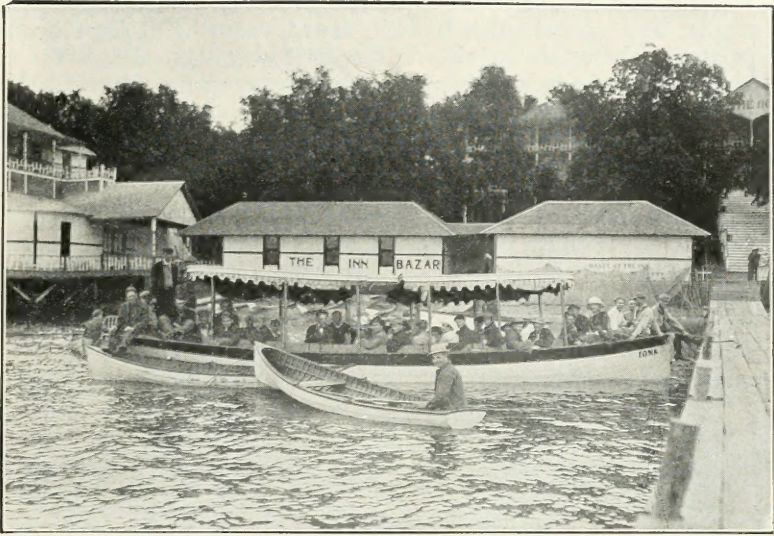


Group Picture—Summer Surveying Camp—1912.

ORGANIZATION AND MANAGEMENT.

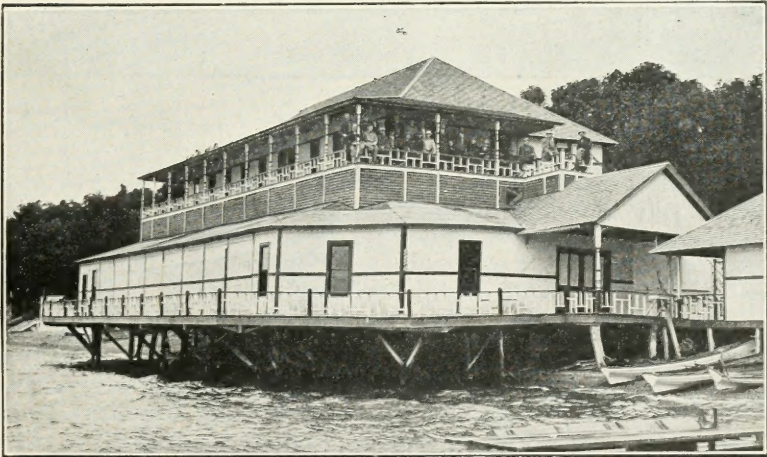
The Summer Surveying Camp is in charge of three or four members of the civil engineering faculty of the college, who plan and supervise the work, and manage the camp. While working along the Des Moines River, headquarters were made in camp, the department furnishing tents, cooking utensils, and other equipment. The region now being surveyed is well known as a summer resort, and it has been found cheaper and more efficient to make headquarters at "The Inn," one of the best-known summer hotels of the region. Under this arrangement, the students pay their own board and lodging expenses, and their transportation expenses to and from camp. For transportation during the progress of the work, the college rents, for the two weeks, several row boats, and a gasoline launch capable of carrying thirty-five persons.

The instruments necessary for the work are selected from the college equipment and expressed to camp a day or two early, so that there will be no delay on this account. The heads of the instruments are placed in the boxes and carried on the train by the students. This makes it unnecessary to go to the trouble of carefully packing each instrument tightly in its box with tissue paper, and the instruments reach camp in better condition.



"The Iona"—Captain B. A. O'Farrel.

The students occupy rooms on the upper floor of the building known as "The Pavilion," situated on the lake shore and somewhat removed from the main part of the hotel.



"The Pavilion"—Student Headquarters at "The Inn."

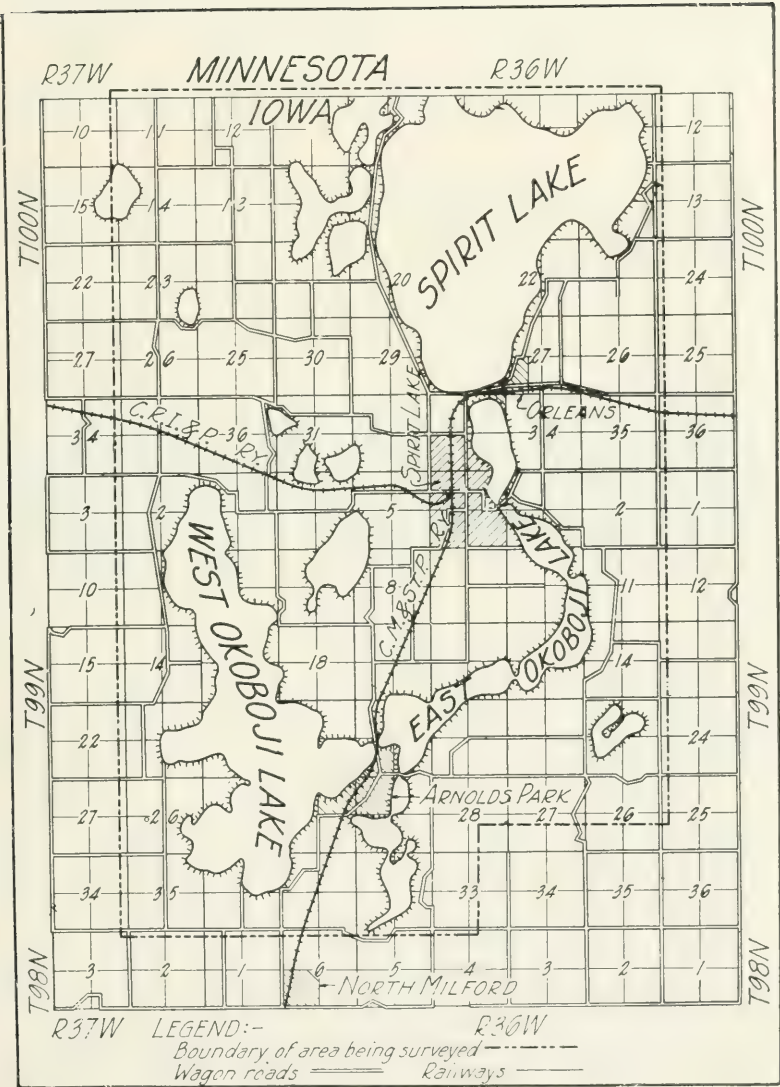
Assignments are made out each evening, immediately after supper, and posted on a bulletin board near the student headquarters, giving the work for the following day, the party on which each man is to serve, and his position in the party. Each student is expected to consult the bulletin board each evening, notice what is to be expected of him on the following day, and be fully prepared to start work in the morning. The personnel of the various parties is changed from time to time, the idea being to give the students as varied a range of experience as is practicable. The entire personnel of a party is never changed at one time, but the changes are made gradually, replacing one or two men at a time, leaving at all times, a majority of the party who are familiar with the work and duties of the party.



Starting for Work.

Work is started at 8:00 A. M. and is usually finished by 5:00 P. M. each day, with an hour at noon for lunch. Those parties who may happen to be working close to headquarters, and who can conveniently do so, return to "The Inn" for lunch, but all others take their lunch into the field with them.

After dinner in the evening there is sometimes computing or drafting work to be done, or stellar observations to be taken, but as a general thing the students are free to spend their time as they may see fit. There are row boats for rent and many spend their evenings in rowing or fishing. In years in which the weather turns warm early, the water is warm enough for bathing. There is available also, a bowling alley for those who enjoy the game,



and facilities for other forms of amusement usually found at summer resorts. In fact, the Summer Surveying Camp offers the students a splendid outing at very slight expense, the cost to a single student being rarely over \$25, including board and room, and transportation expenses from and to Ames.

THE AREA BEING SURVEYED.

The area being surveyed at the present time, will, when the work now planned has been completed, form a tract of land, seven miles east and west by eleven miles north and south, situated in Dickinson County, Iowa, immediately south of the Minnesota line, and including parts of Townships 99 and 100 North, Ranges 36 and 37 West of the Fifth Principal Meridian. This tract lies within the area covered by the last glacial period, known as the Wisconsin Drift Area. The topography is typical glacial topography, successive low hills and depressions with little or no natural drainage, and as a consequence, many ponds, lakes, and marshes. In wet seasons nearly every little depression contains water and the formation seems to be such that water thus caught does not drain away rapidly, even though the depression may be at a considerable elevation. What streams there are are small and not well defined, and usually wind here and there in very crooked courses. Most of the lakes and ponds are of small size and very shallow, the great majority of them disappearing entirely after a succession of several dry years. There are, however, three lakes of considerable size; East and West Okoboji Lakes in the southern part of the area being surveyed, and Spirit Lake farther north. Of these, the first and last are comparatively shallow, not exceeding 40 feet in greatest depth, whereas West Okoboji Lake has a maximum depth of over 130 feet.

The lakes are spring fed, as there are no streams of any size emptying into any of them, and the smaller ones are formed by water caught in depressions at times of heavy rainfall, and held there until evaporated.

West and East Okoboji Lakes and the Gar Lakes—Upper Gar Lake, Minnewashta Lake, and Lower Gar Lake—are all connected, and the outlet of the system is through the Gar Lakes, through Milford Creek into the Little Sioux River. Spirit Lake is at a slightly higher elevation than East Okoboji Lake with which it is connected by a narrow channel through which the water flows swiftly in years of high water. In years of low water, there is no flow in this connecting channel, and Spirit Lake is cut off from the other lakes of the system at such times, and then has no outlet. This has been the case for the last four years.

The land near the lakes is very rolling, inclined to be stony, and the lower parts, in wet seasons, as well as depressions in the higher lands, cannot be cultivated, but the higher lands, away from the lakes, are farmed to a considerable extent, and are considered good farming lands. The land immediately bordering the lakes is quite largely meadow, with a narrow fringe of scrub oak timber next the water, and extending back inland for a short distance, seldom more than one-quarter mile.



Looking from Triangulation Station 12 Westward toward Center Lake.

The area now being surveyed is very well suited to the work in hand. It is easy of access, being reached by either the Chicago, Milwaukee and Saint Paul Railway, stopping at Arnold's Park, or Spirit Lake, or at Okoboji Station during the summer season, and also by the Chicago, Rock Island and Pacific Railway, stopping at Spirit Lake, or in the summer season, at West Okoboji Station. It offers a great variety of problems for the surveyor, because of its strong relief, its great area of water surface, and its great length of shore line. It is, as has been mentioned, famous as a summer resort, its population at the height of the season being probably somewhat over 5,000. It is a beautiful and picturesque region and affords good boating, fishing and bathing. It is also rich in historical interest, having been in the early days the home of the Okoboji tribe of Indians, and the scene of one of the bloodiest massacres in the history of the development of the middle West. This region has never been accurately surveyed and mapped, so that it is thought that the map accompanying this bulletin may find considerable use among the people of the state.

GENERAL OUTLINE OF WORK.

Work was first started upon West Okoboji Lake with "The Inn," as headquarters, and was carried both north and south along both shores of that lake, carrying the work as far north as the C., R. I. & P. track. Work was then started in the southwestern corner of the tract and carried east along the southern boundary of the tract, and then north along the eastern boundary along both shores of East Okoboji Lake. It will be seen, by reference to the maps, that the work in the vicinity of Okoboji Lakes is very nearly completed, and there remains the surveying of the territory adjacent to the northern end of East Okoboji Lake, and that surrounding and west of Spirit Lake, as far north as the Minnesota line. This will necessitate a change of headquarters at an early date, in order that the work may be reached without great loss of time in going to and returning from work.

The work being done consists of six distinct parts, namely:—Reconnaissance for Triangulation, Base Line Measurement, Triangulation, Taking Topography, Leveling, and Sounding. The work is usually so arranged that work along all of these different lines, or as many of them as is practicable, is being done at all times. The Base Line Measurement is carried on only as new base lines are needed, and thus far there have been measured only two, with the possibility of one other in the near future. The Reconnaissance for Triangulation is kept considerably in advance of the rest of the work for obvious reasons, in fact, reconnaissance for the triangulation of the region around Spirit Lake is being carried on at the present time, but the topography parties will not reach that part of the area for several years. By that time the triangulation stations will have been established, and the angles read, so that the azimuths and distances will be available for use in taking topography. The Triangulation follows closely upon the Reconnaissance. The Leveling comes next, and when completed, and when bench marks have been established and the elevations adjusted, everything is ready for Taking Topography or the actual sketching of the map. The Sounding may be done at any time after the triangulation is complete.

TRIANGULATION STATIONS.

In order to have an accurate frame work on which to hang the more detailed topographic work, a triangulation system has been laid out and is being extended as the progress of the work demands. (See the map of the triangulation system.) The positions of the triangulation stations are selected after a careful reconnaissance, in which use is made of field glasses and pocket

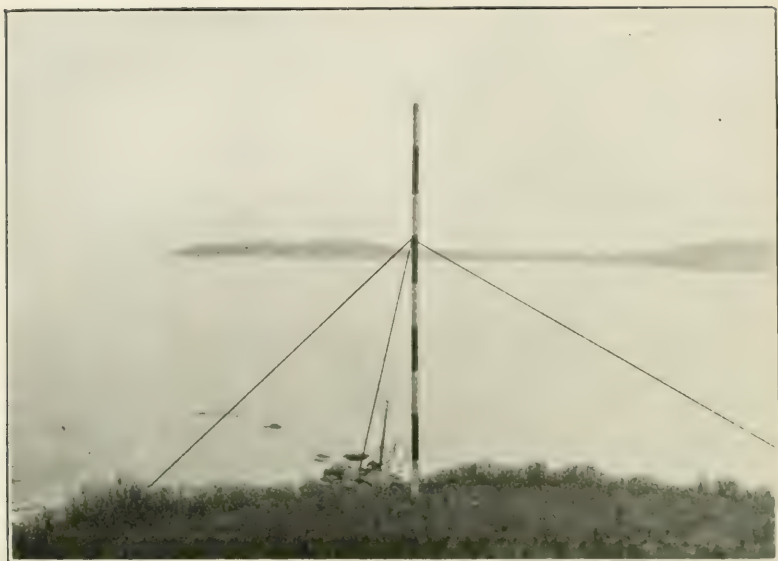
compasses. The points to be considered in selecting the triangulation stations are:—The selection of points from which a good view can be had in nearly every direction, or at any rate in the directions in which sights must be taken; and the formation of strong figures.

As it is not anticipated that these triangulation points will be needed for a longer period than five to ten years, they have been marked by 2"x4" yellow pine stakes about 3 feet long. In the top of each stake is bored a hole, $\frac{3}{8}$ " in diameter, and 4" deep, and a strip of tin is tacked around the top of the stake to prevent splitting in driving. After the stake has been driven flush with, or a little below, the surface of the ground, an iron pin, slightly largely in diameter than the hole and 6" long, is driven into the hole in the top of the stake, projecting 2". This pin serves to mark the exact point of the triangulation station, and also as a support for the bottom of the signal. Each triangulation station is carefully tied in to the prominent features of the landscape, and a careful description, illustrated by sketches and in some instances by photographs, is written up in the "Reference Book." By using this book, it is possible to find the stations at any time, even after the stake itself has entirely decayed. It would be possible, by means of these notes, to find all of the triangulation stations and set permanent monuments, in case it should ever seem advisable to do so.

There has been no occasion, thus far, to use elevated instrument stations, or high signals, although it is expected that some use will be found for the former in the near future, in surveying the region around Spirit Lake, where the land has much less relief, and where high points for stations are not to be found.

The signals have consisted of a 2"x4" pine scantling, 16 feet long, painted black and white in alternate bands of about 2 feet in width. The signals are banded at both ends with strips of tin for protection against battering or splitting, and the lower end is bored to fit over the iron pins which project from the tops of the triangulation station stakes. This keeps the bottoms of the signals always at the proper point, and the tops are held in place by guy wires attached to the signals at a point 12 feet from the ground, extended out in three directions making an angle of 120 degrees with each other in plan, and fastened to stakes driven in the ground at a distance of about 10 feet from the base of the signal. This makes a signal which is extremely portable, is easily taken down and put up, and one which serves very well for comparatively short sights.

In some instances, where trees or other obstructions made it necessary to use higher signals, two of the 16-foot signals were



Signal on Triangulation Station 3—Pillsbury's Point.

lapped 2 feet and bolted together. The guy wires were arranged in two sets of three wires each, attached to the signal at points 12 feet and 22 feet above the ground, and were fastened to stakes set 10 and 20 feet from the bottom of the signal, the two sets of guy wires being made to alternate in plan.

On some of the longer and more difficult shots, especially at times of day when it was necessary to look in the general direction of the sun, it was found difficult to distinguish the signals from telephone poles. To overcome this objection, it is planned to use a signal with two cross arms, each 8 feet long and painted in the same manner as the signal itself. These cross arms will be bolted to the signal at a point 6 feet below the top and will be placed horizontally and at right angles to each other. This will make a signal on which a cross arm will be seen when looking from any direction, and it is expected to do away with the difficulty mentioned. On sights away from the sun, the alternate bands of black and white show up plainly, and there has been no difficulty on this account.

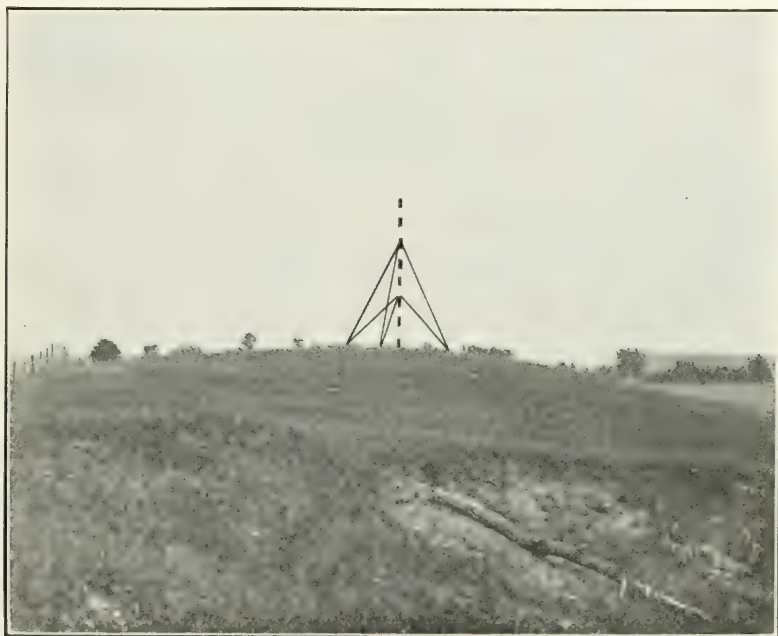
BASE LINE MEASUREMENT.

Two base lines have been used on the work thus far, one, the line between triangulation stations 5 and 8, and the other, the

line between triangulation stations 15 and 16. It is expected that one additional base line will be measured at some convenient location near Spirit Lake, not so much because it is necessary, as to give the students experience in this class of work. The line 5 to 8 was the original base line, and from it most of the triangulation was calculated, the line 15 to 16 being used largely as a check base.

Both base lines were measured both forward and backward over the line with a 300-foot standard steel tape, using the normal tension for the tape, and correcting for grade, temperature, and reduction to sea level. By normal tension is meant that tension for which the increase in length, due to stretch, is exactly balanced by the shortening due to sag between supports. When using the normal tension, therefore, no corrections for sag and pull are necessary.

The method used in measuring the base lines is as follows: The line is first run out with a transit, and chained carefully, a 2"x4" pine stake being set at the end of every 300 feet, the 4" dimension of the stake being placed in the direction of the line. In first running out the line, these stakes are driven only lightly,

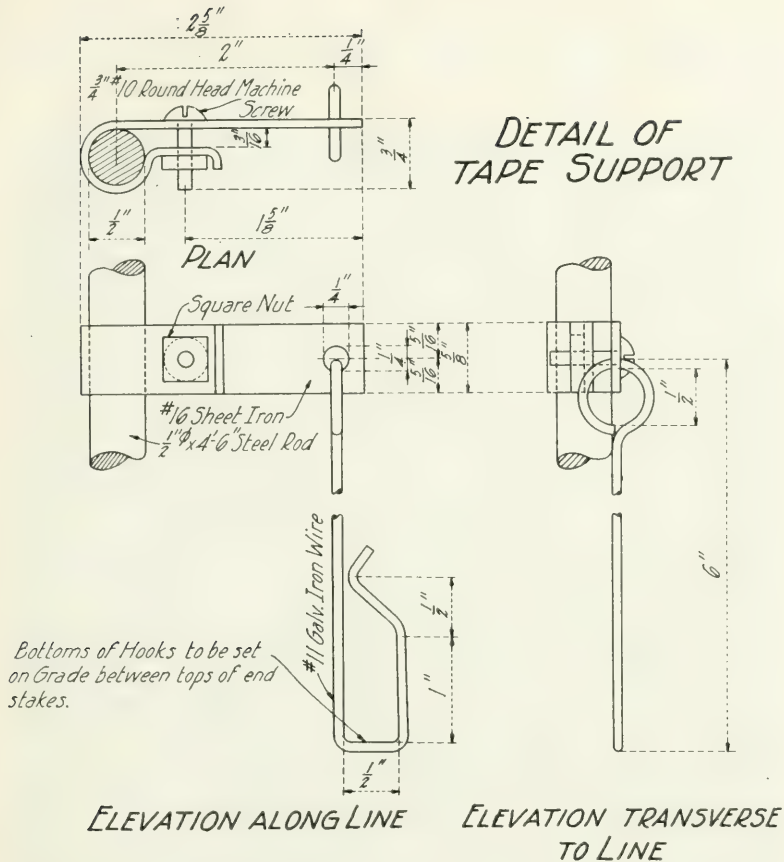


Double Signal on Triangulation Station 12.

as it will probably be necessary to move some of them forward or backward along the line when the actual measurement is made. To the top of each stake is tacked a small piece of sheet zinc $1\frac{1}{4} \times 3\frac{1}{2}$ ", to receive the scratch marking the end of the tape length. The stakes are allowed to extend about 1 foot above the ground, or as much as $1\frac{1}{2}$ feet in cases where it is necessary in order to have the tape clear the long grass. In starting the measurement, stakes are driven until solid, and until their tops are on the desired grade. The grades are fixed so as to change grade as few times as possible, and when necessary, always at one of the stakes. The grades are planned a few stakes ahead by the level party, but the stakes are not finally driven until the measurement reaches them, as otherwise it will almost certainly be found necessary to move some of them, as it is almost impossible when setting them in the first place to allow for the sag. The final elevations of the tops of all stakes are recorded by the level party and furnish the information necessary for the calculation of the grade correction. The supports for the tape are lined in between the stakes at intervals of 25 feet, and consist of $\frac{1}{2}$ " round steel rods, $4\frac{1}{2}$ feet long, driven into the ground until they are firm. They are supplied with a sliding clamp which may be adjusted at any desired height on the rod by means of a machine screw and nut, the only tool necessary being a small screw driver. These clamps carry wire hooks in which the tape rests, and the bottoms of the hooks are all placed on grade between the end stakes, by the level party. The construction of the tape supports will be readily understood by referring to the sketch shown herewith.

The tension is measured by a spring balance at the forward end of the tape. To secure a steady pull, use is made of levers, one at each end of the tape, consisting of sections of flagpole about $4\frac{1}{2}$ feet long, having, about one foot above the shoe, a common screw hook to which the end of the tape is attached. The iron shoe is forced into the ground to serve as a fulcrum, and the tension thus applied. The lever man at the rear end of the tape has only to keep the zero of the tape above the scratch on the zinc plate which is tacked to the top of the stake. The lever man at the forward end has only to keep the tension at the correct amount. The temperature is read at the quarter points of each tape length by means of mercurial thermometers.

The party for base line work consists of:—1 Chief-of-Party, who has general direction of the work, 1 Transit-man, who lines in the stakes and tape supports, 1 Stake-man, who drives the stakes and sets the tape supports, 1 Level-man, and 1 Level Rod-man, who run levels over the tops of the stakes, determine the grades to be used, assist the Stake-man in setting the bottoms of the hooks on grade, and record all data necessary to calculate the grade correction, 1 Marker, who makes the scratch at the end of



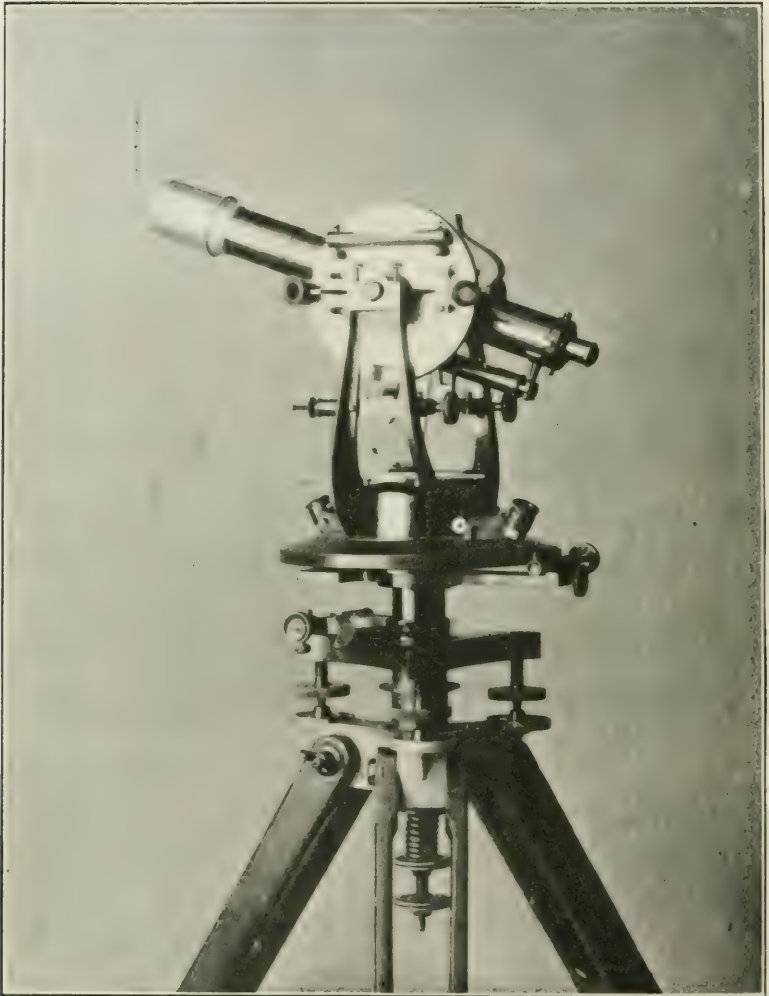
Sketch showing Details of Tape Support.

each tape length, and also assists the forward Lever-man in getting the tension at the required amount, 2 Thermometer-men, who read the temperature, and make themselves generally useful, 2 Lever-men, who apply the tension, and 1 Recorder, who keeps all of the notes except those for the leveling, 10 men in all. In case only 5 or 6 men are available, the party doing the actual work of measurement, may also do the work of lining in and leveling. The accuracy attained in this work has been about 1 in 30,000.

TRIANGULATION.

The angles of the triangulation system have been read by one

of two methods. In the first method, a 7" Fauth & Co. Repeating Theodolite, reading by two opposite verniers to 10 seconds of arc is used. A photograph of this instrument is shown herewith.

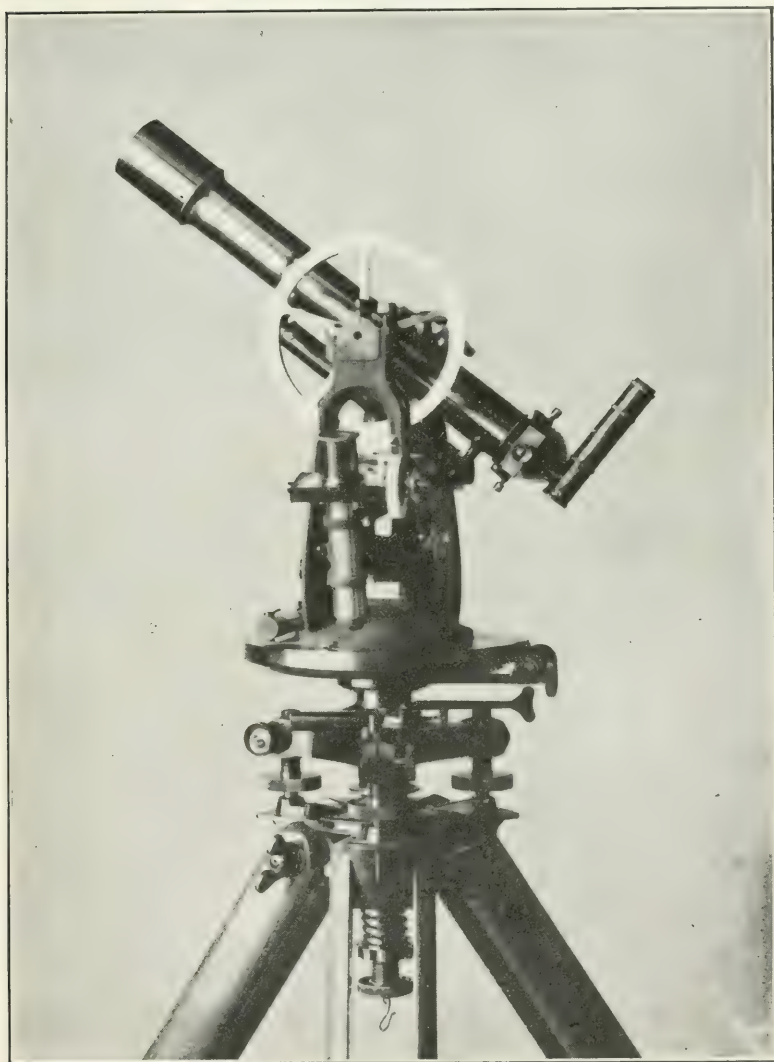


7-Inch Repeating Theodolite.

The instrument, when in use, is protected from the sun and wind by a large wagon umbrella. The repetition method is used, six repetitions being taken with the telescope direct, turning from left

to right, and reading both verniers, then six repetitions with the telescope reversed, turning from right to left, and reading both verniers. The mean of the two values thus obtained is taken as the value of the angle

In the second method, a 6" Buff & Buff Altazimuth, reading



6-Inch Altazimuth Instrument.



Triangulation Party.

by two opposite micrometer microscopes, to single seconds, is used. A photograph of this instrument is shown herewith, and gives a fairly good idea of the instrument. The angles around any one triangulation station are read by series, turning from left to right with the telescope direct, and then from right to left with the telescope reversed. The mean of the two pointings on any one line, is taken as the value of such pointing, for that set of angles. Five sets are read at each station, each set commencing at a different point on the graduated circle of the instrument, the five starting points being so arranged as to cover thoroughly the whole graduated circle, and thus eliminate any error due to errors in the graduation of the instrument. The mean values of the angles as calculated from the pointings of the five sets, are taken as the values of such angles.

The Triangulation Party consists of:—1 Chief-of-Party, who has general supervision of the work, 1 Instrument-man, who points the instrument and reads one vernier, or one micrometer, 1 Vernier-man, who reads the other vernier or micrometer, 1 Umbrella-man, who shades the instrument with the umbrella, and 1 Recorder, who keeps the notes of the party, 5 men in all. If necessary to cut down the size of the party, the Chief-of-Party serves as Vernier-man, and may also keep the notes, reducing the party to 3 men.

AZIMUTH DETERMINATIONS.

Azimuth determinations have been carried on, extending over a period of several years, by both Polaris and Solar observations, so that the azimuth is now known with considerable accuracy. For this purpose, a line known as "The Azimuth Reference Line," has been laid out near "The Inn," in a position suitable for either solar or stellar observations, its azimuth has been determined, and angles read from its extremities to triangulation stations 3 and 4, thus furnishing a means of calculating the azimuths of all lines of the triangulation system. These azimuths are shown on the map of the triangulation system to the nearest minute of an arc, although they have been calculated much more closely. The term azimuth, as here used, means the direction of any line with respect to a true south line, measured in the direction west, north, east.

CALCULATION OF TRIANGULATION.

After the base line had been measured, and a number of the angles read, the triangulation was calculated. This work has been done at Ames, during the school year, with the assistance of the Junior students, in connection with their work in Astronomy and Geodesy. The angles in each quadrilateral of the system are tabulated, and adjusted so that their values are consistent with each other. Having the correct values for the angles, the lengths of the lines of the system are calculated and tabulated. These lengths are given to the nearest foot on the map of the triangulation system which accompanies this bulletin.

LEVELING.

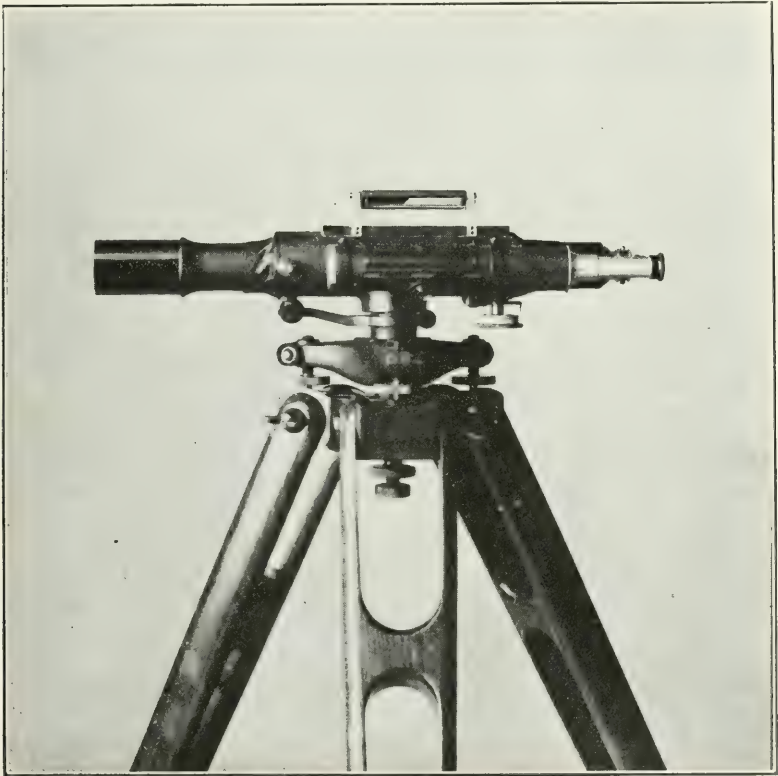
For all topographic work in the immediate vicinity of the lakes, elevations were secured from, and checked upon, the water level of the lakes. A bench mark has been established near "The Inn," and its elevation determined. At the beginning of each camp, the elevation of the water level of the lakes is determined by comparison with this bench mark. The lake level varies considerably from year to year, and slightly during any one season, so that the relation must be established anew each year. The level of the water in West Okoboji Lake, at the time of the summer camp of 1905 has been taken as the datum, or zero elevation, and all elevations given on the maps, or in this bulletin are referred to this datum. The lake level has at different times varied something over two feet each way from this zero elevation, and may show even greater variations.

The relation between the datum of the present survey, and mean sea level is not exactly known. Assuming the elevations on the Spencer and Spirit Lake division of the Chicago, Milwaukee, and Saint Paul Railway to be correct, our datum, the lake level of 1905, is at elevation 1,395 feet above mean tide level at New York. An effort was made to check this elevation in various ways. The Chicago, Rock Island, and Pacific Railway in running their levels through this region, have not used elevations referred to sea level, and there seems to be no way of reducing their elevations to sea level elevations. The United States Geological Survey has run level lines at various points in the state of Iowa, but not in the region under survey. The Geological Survey, has, however, elevations at various points along the Chicago, Milwaukee, and Saint Paul Railway, in other parts of the state, and by comparing these with the elevations as furnished by the railway company, a rough check may be secured. By this process it has been determined that the elevation as given for the level of water in the lakes—1,395 feet—is nearly correct, and it is safe to assume that that elevation is not more than 5 feet in error, and probably not so much as that.

For the topographic work at a considerable distance from the lake, it is not feasible to carry elevation from lake level, by the stadia method as has been done for the points nearer the lakes. It has, therefore, been necessary to run level circuits, determine the elevations of many of the triangulation stations, and establish bench marks in convenient places. This work has been done with Precise Level and Self-Reading Rod, using as turning points steel pins driven into the ground. These turning pins are made of steel, and are 12" long, tapering toward the lower end, and have an enlarged head to receive the bottom of the rod. The exact design of the head depends upon the type of rod to be used. For the ordinary type of Philadelphia Rod, which was used upon some of the leveling work, the head was made convex upward. It was, of course, necessary to use care in driving this form of pin, in order that the head might not become jammed, and for this reason the pins were driven with a wooden-faced hammer or mallet. For use with the Precise Level Rods, of the type used by the United States Geological Survey, which were used upon the greater part of the work, the head of the pin was made with a slight concave depression in the top, to fit the brass shoe of this type of rod, which is slightly convex downward. All of the pins have a ring fitting around the shank, just below the head, to which is attached a chain by means of which they are pulled up when no longer needed. In removing them from the ground, all that is necessary is a slight blow on the side, after which they may be easily pulled out by the chain, and may then be set ahead in a new position.

On the first of the leveling work, which was done in connection with this survey, a Bausch-Lomb-Saegmuller wye level, having a sensitive bubble, and a micrometer screw under the rear wye was used. This instrument is supplied with stadia hairs, and all three horizontal hairs were read, giving not only a better value for the rod reading, but also the means of calculating the length of the sight. Rods of the ordinary Philadelphia type were used with this instrument. In other respects, the method of procedure was the same as that given for the Precise Level, and described below.

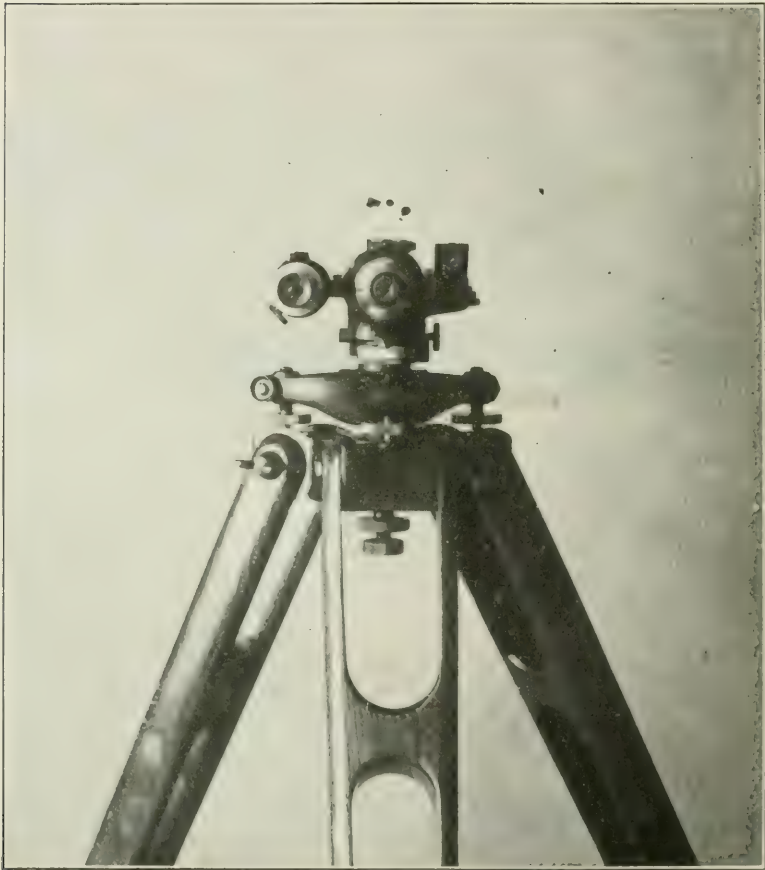
The later work has been done with a C. L. Berger & Sons precise level of the Coast Survey type, and self-reading rods of the type used in precise level work, by the United States Geological Survey. The Coast Survey level has an extremely sensitive bubble, and a micrometer screw under the eye piece end of the telescope, for delicate leveling. Arrangement is made, by



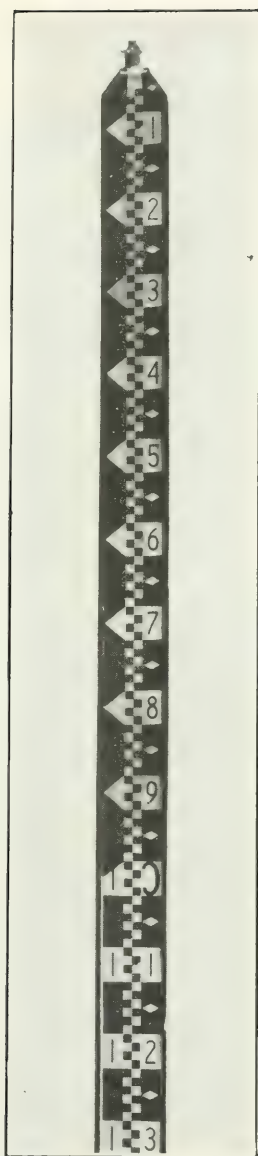
The Coast Survey Type of Precise Level—Side View.

means of glass prisms, so that the leveler may see, with his left eye, the bubble, at the time he is taking the rod reading with his right eye, and may thus keep the bubble exactly in the center of its run at such times. The instrument has three horizontal hairs. Photographs of this instrument as shown herewith.

The rods used with this instrument are of the self-reading type, and are graduated to yards and hundredths of yards, the numerals being inverted so that they will appear erect through the level telescope, which has an inverting eye piece. The rod has, on the back, a circular spirit level, for use in plumbing the rod, which folds against the rod when not in use, and a mercurial thermometer in a wooden case. In using the instrument, all three



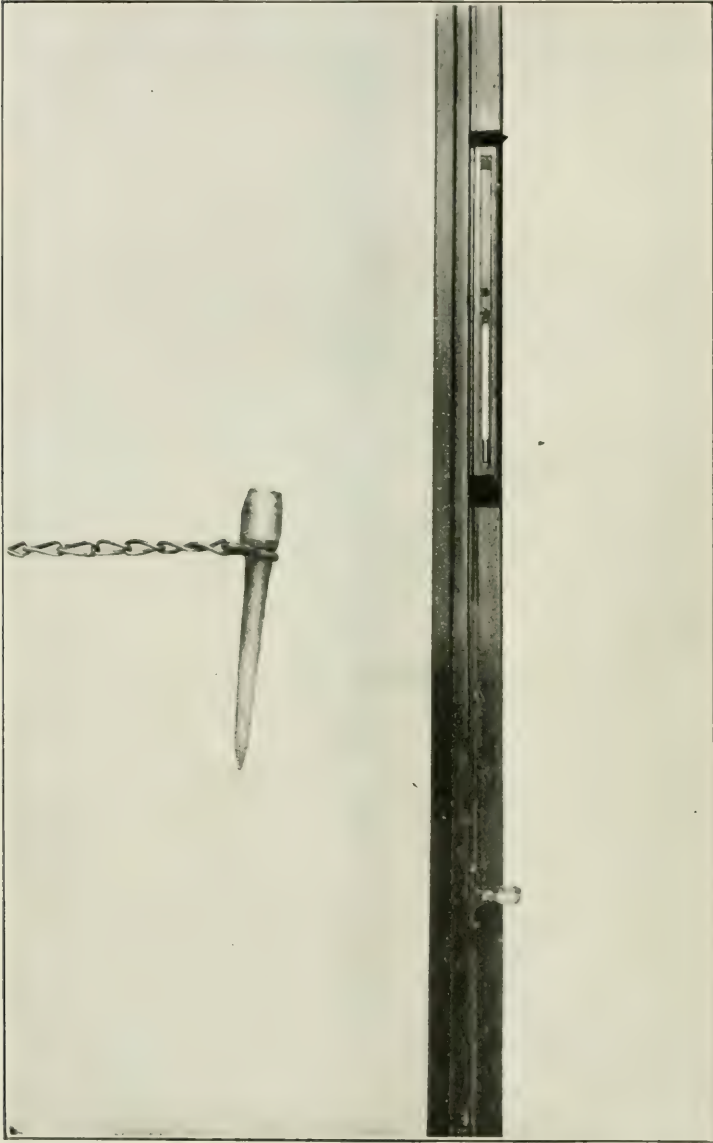
The Coast Survey Type of Precise Level—End View.



Precise Level Rod—Details of Graduation.

horizontal hairs are read and recorded, the sum of the three readings in yards, giving the mean of the three in feet. The

intervals between the readings of the upper and center wires and the center and lower ones, are tested for equality at each reading,



Back of Precise Level Rod and Turning Pin.

and in cases showing a greater difference than the one one-thousandth of a yard, all three readings are re-taken. From the readings of the upper and lower hairs, the length of the sight is calculated by the ordinary stadia formulas. It is required that the sum of the back-sight lengths be made equal to the sum of the foresight lengths in the long run, and that each back-sight be made as nearly equal to the corresponding foresight as is possible. The levels are run forward and backward over the line in circuits of about one mile in length, each circuit closing upon its starting point, and different turning points being used on the forward and backward parts of the circuit. The error of closure must not exceed 0.04 feet times the square root of the distance in miles, the distance being that between the forward and rear bench marks of the circuit, that is, the return levels, which are run in order to close the circuit, are not considered in calculating the distance run. Any circuit showing a greater error than this is re-run. The instrument is, when necessary, shielded from the wind and sun by a large wagon umbrella. Bench marks are set about one-half mile apart, and a careful description of each one is written up in the notes, so that they may be easily found.



A Precise Level Party.

The Precise Level Party consists of:—1 Chief-of-Party, who has general charge of the party, selects the route to be traversed, and picks out the locations of the bench marks, 1 Level-man, who runs the level, 2 Rodmen, who serve as back-sight and fore-sight

rodman, alternately, 1 Umbrella-man, whose duty it is, to shield the instrument from the wind and sun, and 1 Recorder, who keeps the notes, writes up the descriptions of the bench marks, and checks the equality of the intervals between the upper and center, and center and lower wire readings.

TAKING TOPOGRAPHY.

Basing their work upon the adjusted triangulation system, the topography parties have mapped the country, using either the transit and stadia, or plane table and stadia method. The former has been more used, because, in this region, the weather is not usually favorable for plane table work, as it is often necessary to work in damp weather.

Each topography party is given, for reference, a small blue print from a photograph of the map, showing exactly what has been done, and what remains to be done, a small blue print showing the triangulation system, and giving the azimuth and length of each line of the system, and a small blue print from a tracing showing the location of the prominent features of the landscape in a general way, and very similar to the drawing from which the illustration showing the area which is being surveyed, and which is reproduced on page 9, was made. These blue print maps are of great value to the parties, as from them they can see what topography remains to be taken, what the azimuth and length of any line of the triangulation system is, and where the roads, railroads and other features of the landscape are located, a great help in keeping one's bearings in a strange country.

The topography party starting work, sets up at that station of the triangulation system which is most convenient, sights upon all others which may be visible, thus securing the azimuth, and usually the elevation also, since the elevations of nearly all of the triangulation stations are known. In case the elevation of the particular triangulation station being used is not known, the elevation is secured from the nearest bench mark of the level system. Stadia traverse is then run in such a way as to cover the area which it is desired to map, taking side shots for topography from each station of the traverse. The stadia readings are reduced immediately, by stadia slide rule and recorded in the notes. The draftsman, carrying with him, a small drawing board and protractor sheets, and using the transit box as a seat, plots the readings as fast as they are reduced and sketches in the details, in pencil, using a scale of 1 inch equals 400 feet. The protractor sheets are simply sheets of drawing paper, 16"x20" having a 14" full circle protractor engraved upon them. The draftsman, by means of two large draftsman's triangles, transfers the azimuth

from the protractor to any point on the sheet, scales off the proper distance, and writes on the elevation of the point. Elevations are given to tenths of feet, and are so written on the field sheet, the point on the map which represents the point in question being used as the decimal point in the elevation. Thus, 36.7 means that the point on the map at which the decimal point comes, is at an elevation of 36.7 feet. Having a number of such points located, and their elevations written on, the draftsman is enabled to sketch in the topography, showing the traverse line; all side shot points with their elevations; all fences, trails, roads, railroads, prominent buildings, etc.; all ponds, sloughs, lakes, streams, or other water features; the ten-foot contour lines; and the growth, that is, whether the land is timbered or not, whether cultivated or meadow, etc. The draftsman is required to sketch in all the topography at each station on the traverse before going to the next, and it sometimes becomes necessary for the balance of the party to stop work for a time, in order that the draftsman may catch up. On bright days, the glare of the sun from the white paper is very trying to the eyes, and a light shelter is erected to shade the draftsman and note keeper. These shelters are pieces of light duck, six feet square, which are set up with two short poles at the front, the rear sloping down to the ground and fastened down by a rope at each corner. There are also ropes at the two front corners to guy the poles.

There has been some difficulty in getting the draftsman to look around at the country as he sketches, and it is planned to experiment in the near future, with a system which it is thought will remedy this fault. The drawing board, instead of being carried on the lap of the draftsman, will be mounted on a tripod, and it will be necessary for the draftsman to stand at his work, putting him in a much better position to observe the surrounding country. It is expected that this system will result in a much better grade of topography without the locating of a greater number of points on the field sheet.

The traverse lines are made to close upon themselves, each other, or upon the triangulation system, at every opportunity, so that all errors may be found and corrected before the work has gone any considerable distance. Plotting checks are also introduced into the work whenever possible. One of the field sheets will, in general, be sufficient for the mapping of one square mile of country, but the draftsman always carries extra sheets for use in case they are needed.

The Topography Party, using transit and stadia method, consists of:—1 Chief-of-Party, who has general charge of the party, who selects the route to be followed by the traverse, and directs the movements of the rodmen, 1 Transit-man, who performs the



Topography Party.

instrument work, 1 Recorder, who keeps the notes and reduces the stadia readings by slide rule, 1 Draftsman, and 2 or 3 Rodmen.



Plane Table Party.

The number of rodmen that can be used to good advantage, depends upon the nature of the country being mapped. Under ordinary conditions, a good transit-man can take readings as fast as two good rodmen can give them to him.

Topography parties, using the plane table, follow nearly the same line of procedure as the parties using the transit. The Transit-man and Draftsman are necessarily combined in the position of Instrumentman, the drafting being done on the plane table sheet as the readings are taken. There are no azimuths to record, and the only notes taken are the distances along the traverse line. The plane table method is not so rapid as the transit and stadia method, because the Instrument-man has all of the sketching to do, but has the advantage that all the sketching is done by the man who takes the readings and who is in a position to observe the country as he works. In addition, work can be done with a somewhat smaller party than is required for transit topography.

SOUNDING.

All lakes of any size are being sounded and the results plotted on a special sounding map, a reproduction of which accompanies this bulletin. In the smaller lakes, and in those parts of the larger lakes, in which the water is too shallow to allow of the use of the launch, this work has been done from rowboats, the depths being measured with a sounding rod, consisting of 12 feet of $\frac{3}{4}$ " galvanized iron pipe, having a tee on the lower end, and graduated to feet. Soundings are taken only to the nearest foot.

In deeper water and wherever possible on the larger lakes, the sounding work has been done from the launch. The water is quite generally too deep to be sounded with a rod, and use is made of a sounding line very similar to those used by the United States Coast and Geodetic Survey, and by the United States Navy. The sounding weights are of lead and are made in two weights, 9 pounds and 15 pounds, respectively, the former being intended for use in comparatively shallow water, and the latter in deep water. The lead line is made from Silver Lake Sash Cord, which has been soaked in water, and manipulated, until the starch is all removed, and the line is soft and pliable. The line should also be thoroughly stretched, and the best way to accomplish this is to drag the full length of the line, with the 15-pound weight attached after the launch for a day or so. The lead line is graduated to feet, being in this respect different from the lines used by the Coast Survey, and the Navy, which are marked in fathoms. It was thought that depths in feet would mean more to the persons who will receive this bulletin, than depths in fathoms. The markings on the line are made by means of leather tags of differ-

ent shapes, and by variously colored pieces of cloth, so that the experienced leadsman can tell at a glance just what the reading is.

In using the lead line, the launch is run across the lake, keeping as nearly a straight line as possible, and at such a speed as is best suited to the depth of water to be sounded. In deep water it has been found that the speed must be cut down materially, because the leadsman, being only a few feet above the water, cannot heave the lead farther ahead than about 30 or 40 feet, and the lead must have reached the bottom by the time the launch has come over it. The leadsman stands on the bow of the boat, swings the lead over his head once or twice, and heaves it as far ahead as possible. When the launch comes over the lead, and the line is vertical, the depth is read and recorded, the time taken, and the line hauled in for another heave. A Signal-man stationed on the stern of the launch waves a flag as each reading is taken, thus notifying the shore parties.



Sounding Party.

To locate the points at which the soundings are taken, two transits are set up at convenient points on shore and each transit-man reads the azimuth of the launch each time that a signal is given from the launch. It is necessary that these points be connected in some way with the triangulation system, so that they may be plotted on the map, and it is also necessary that there must be available at each instrument station, some reference line from which the azimuth may be obtained, and upon which it may be checked from time to time. The usual method has been to run

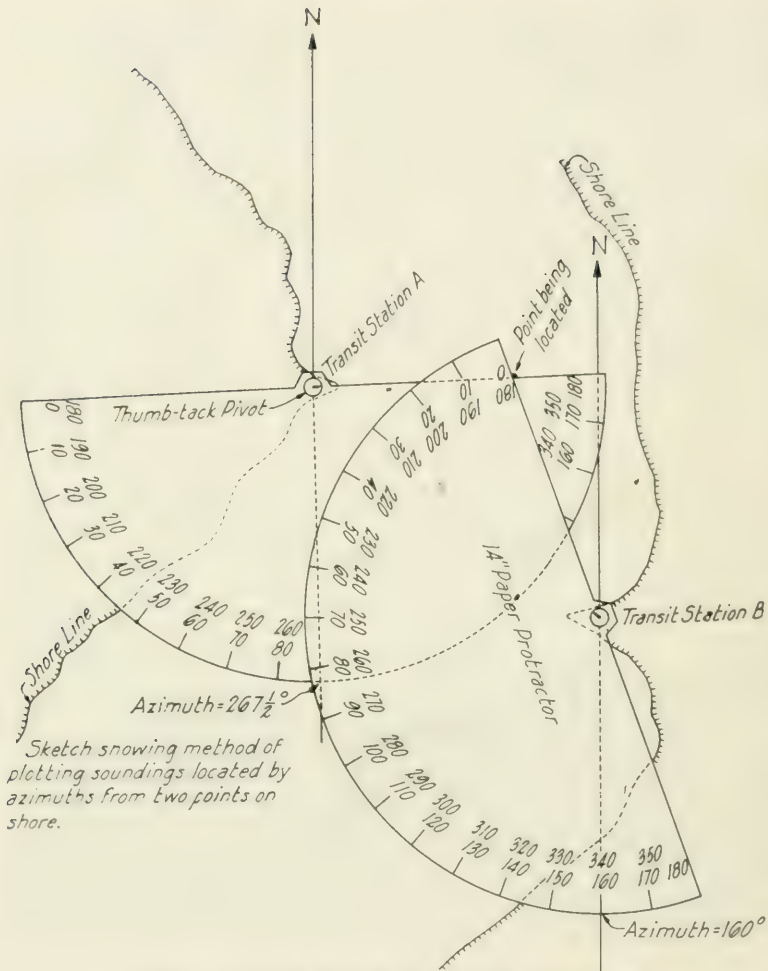
stadia traverse from the nearest triangulation station to each of the proposed instrument stations, and the reference line for azimuth has usually been the line connecting the two stations, so that each instrument-man has only to sight upon the other station in order to check his azimuth. Having his transit once carefully oriented, the transit-man at each station follows the launch with the upper motion of his transit, sighting upon a large lantern upon the front of the awning of the launch. The upper motion is never clamped, as there is not available sufficient time to clamp and make an exact bisection, as the launch is always in motion, and the readings have to be taken, "on the run," so to speak. The azimuth can usually be read to the nearest 15 minutes of arc without clamping, and this is as close as they can be plotted on the map, and as close as one is warranted in reading, inasmuch as the method of noting the depths on the map will probably result in as great an error. Even under the most unfavorable conditions the error made in using this method would not amount to as much as 0.02 inches, on the resulting map, and the error on the reproduction of the map which accompanies this bulletin is negligible. At each transit station, there is stationed a recorder and time-keeper, who keeps the notes and also records the time of each observation. It is essential that the watches of the three time-keepers, the two on shore, and the one on the launch, should be accurate, should have a very small rate, and should be frequently compared. The time is taken simply as a means of picking out from the three sets of notes, those readings which belong together.

The soundings thus taken are plotted on the map by pivoting a 14" semi-circular protractor, usually cut from one of the topography field sheets, at each of the shore stations, and laying off both azimuths simultaneously. The protractors, for convenience, should be of such size that they will overlap for all ordinary positions, and it is only necessary to lay off the proper azimuth with each protractor, and place a point at the intersection of the straight sides of the two protractors, this being the point desired. Reference to the following figure will make the method clear.

The Shore Party for sounding work consists of:—1 Transit-man, who reads the azimuth of the launch at each signal, 1 Time-keeper, who notes the time of each signal, and 1 Recorder, who keeps the notes. The last two positions may be consolidated, if necessary.

The Boat Party, when using row-boats, consists of:—1 Leads-man, who reads the depth, 1 Signal-man, who waves the flag at each reading, 1 Time-keeper and Recorder, and 1 or 2 Oarsmen. 1 Chief-of-Party, on shore, has charge of both Boat Party, and Shore Parties, and has general charge of the work.

The Boat Party, when using the launch, consists of:—1 Chief-



Sketch Showing Method of Plotting Soundings.

of-Party, who also has charge of the Shore Parties, the Captain of the launch, 1 Leadsman, 1 Assistant Leadsman, who helps haul in the line after each heave, 1 Signal-man, 1 Recorder, and 1 Time-keeper. The party may be reduced by one or two men by combining the duties of two of the positions under one man.

It will be noted that the greatest depth shown for West Oko-boji Lake on the sounding map, is 132 feet, a short distance off of Pillsbury's Point. Several persons have claimed to have found greater depths near this point, but a careful search for greater

depths failed to show such. It should be said here that this particular part of the sounding was done under the direction of Mr. B. A. Cole, at one time in the United States Navy, a man who has had considerable experience in this class of work, so that it is safe to assume that this figure, 132 feet, represents the greatest depth.

MAPPING.

The transferring of the data sketched upon the field sheets on a scale of 400 feet to 1 inch, to the final map, which is on a scale of 1,000 feet to 1 inch, and the finishing of the map, is done at Ames, during the school year, by an experienced draftsman. The reduction from the field sheets to the map is accomplished by means of an accurate pantograph, the points on the resulting map being frequently checked by other means.

The drafting work upon the topographic map, from which the map accompanying this bulletin has been reproduced, was done by Mr. R. S. Wallis, Instructor in Civil Engineering.

MAPS.

The maps which accompany this bulletin, are :

(1) A Sounding Map, showing all bodies of water, and the depths of the important ones, so far as they have been sounded up to the present time.

(2) A Map of the Triangulation System, showing all the lines of the triangulation system, with their lengths to the nearest foot, and azimuths, to the nearest minute of arc.

(3) A Topographic Map, showing all railroads, roads, trails, cities, towns, and prominent buildings; all lakes, ponds, sloughs, streams, or other bodies of water; contour lines, or lines of equal elevation, spaced 10 feet apart vertically; the prominent fence lines; and the government section lines.

DATA.

The writer has endeavored to embody in this bulletin all information in regard to methods and results in connection with the Spirit and Okoboji Lakes Survey, which it is practicable to publish at the present time. There is a class of information which may be of some value to engineers and surveyors which is not included in this bulletin, in regard to which information will be given upon request. There have been established a number of

bench marks whose elevations have been carefully determined, and these elevations, together with a description of the bench marks will be furnished any one who will give the locality in which elevations are desired.

Engineers having occasion to use the azimuths given in this bulletin will find it necessary to have a description of the triangulation stations, which will be furnished, upon request.

CONCLUSION.

The work described in this bulletin was first planned by Dean A. Marston, head of the Engineering Division, to whom the inception of the survey is due.

The Summer Surveying Camps have been in charge of various members of the Civil Engineering Faculty, to whom credit should be given, as follows:

Summer Camp 1905—Professors L. E. Ashbaugh and F. C. French.

Summer Camp 1906—Professors L. E. Ashbaugh and F. C. French.

Summer Camp 1907—Professor C. B. Stanton and Mr. Magsaysay.

Summer Camp 1908—Professors C. B. Stanton and H. C. Ford and Mr. S. A. Knapp.

Summer Camp 1909—Professors C. B. Stanton and H. C. Ford and Mr. F. M. Schader.

Summer Camp 1910—Professors C. B. Stanton and H. C. Ford and Mr. V. D. Beard.

Summer Camp 1911—Professors C. B. Stanton, H. C. Ford, R. W. Crum and Mr. B. A. Cole.

Summer Camp 1912—Professors H. C. Ford and R. W. Crum and Messrs. C. Coykendall and R. S. Wallis.

Credit should also be given to Mr. B. A. O'Farrell, captain of the launch, "Iona," for his very capable services, and for the interest he has shown in the work, and to the S. T. Callender Company, managers of "The Inn," for their hospitality and their interest in the work, and in the welfare of the parties.

BULLETINS OF THE ENGINEERING EXPERIMENT STATION

- *No. 1. The Iowa State College Sewage Disposal Plant Investigations.
- *No. 2. Bacteriological Investigations of the Iowa State College Sewage.
- *No. 3. Data of Iowa Sewage and Sewage Disposal.
- *No. 4. Bacteriological Investigations of the Iowa State College Sewage Disposal Plant.
- *No. 5. The Chemical Composition of the Sewage of the Iowa State College Sewage Disposal Plant.
- *No. 6. Tests of Iowa Common Brick.
- *No. 7. Sewage Disposal in Iowa.
- *No. 8. Tests of Dry Press Brick Used in Iowa.
- *No. 9. Notes on Steam Generation with Iowa Coal.
- *No. 10. Dredging by the Hydraulic Method.
- *No. 11. An investigation of Some Iowa Sewage Disposal Systems.
- *Vol. II. No. 6. The Good Roads Problem in Iowa.
- Vol. III. No. 1. Tests of Cement.
- Vol. III. No. 2. State Railroad Taxation.
- *Vol. III. No. 3. Steam Generation with Iowa Coals.
- Vol. III. No. 4. Incandescent Lamp Testing.
- *Vol. III. No. 5. Steam Pipe Covering Tests.
- *Vol. III. No. 6. The Assessment of Drainage Districts.
- Vol. IV. No. 1. Tests of Iowa Limes.
- Vol. IV. No. 2. Holding Power of Nails in Single Shear.
- Vol. IV. No. 3. Miracle Contest Papers for 1908.
- Vol. IV. No. 4. Miracle Prize Papers for 1909.
- Vol. IV. No. 5. Sanitary Examination of Water Supplies.
- Vol. IV. No. 6. Sewage Disposal Plants for Private Houses.
- Bulletin No. 25. Electric Power on the Farm.
- Bulletin No. 26. The Protuction of Excessive Hydrogen Sulfid in Sewage Disposal Plants and Consequent Disintegration of the Concrete.

- Bulletin No. 27. A Study of Iowa Population as Related to Industrial Conditions.
- Bulletin No. 28. History of Road Legislation in Iowa.
- Bulletin No. 29. Costs of Producing Power in Iowa with Iowa Coals.
- Bulletin No. 30. The Determination of Internal Temperature Range in Concrete Arch Bridges.
- Bulletin No. 31. The Theory of Loads on Pipes in Ditches, and Tests of Cement and Clay Drain Tile and Sewer Pipe.
- Bulletin No. 32. A Topographical Survey of the Spirit and Okoboji Lakes Region.

* Out of print.

